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C02F 1/24

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(56) Documents cited

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(58) Field of search
UK CL (Edition L) C1C CJB CJC CJD CKB CKC CKD CLB CLC CLD CRDD CSDD CTDD
INT CL[6] C02F 1/24
Online databases: WPI

(54) Dissolved air flotation

(57) A liquid treatment method and apparatus for removing particulate impurities from a liquid stream, comprises forming a zone of micro gas bubbles from a source 20 across substantially the whole surface area of a treatment vessel 12 which is situated above a filter bed 33, passing liquid to be treated into the vessel 12 above the inlet for the air whereby the liquid passes in counter-current mode through the air bubbles. Liquid may be passed through a flocculator 18 upstream of vessel 12. In vessel 12, bubbles adhere to the particulates causing flotation thereof for removal as scum by overflow 24. The filter 37 may be periodically backwashed.

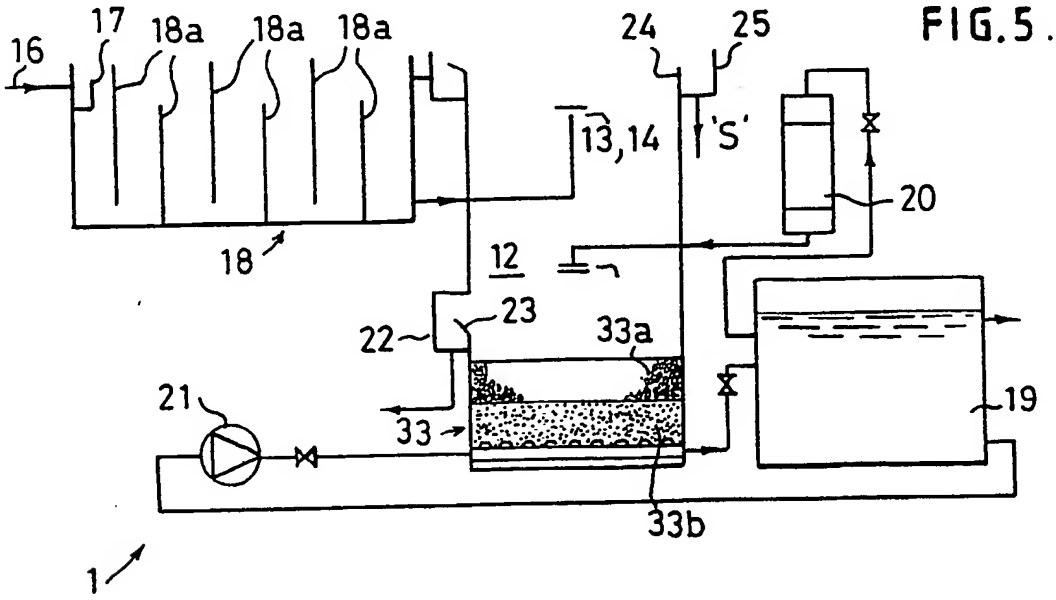

FIG.5.

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FIG.1.

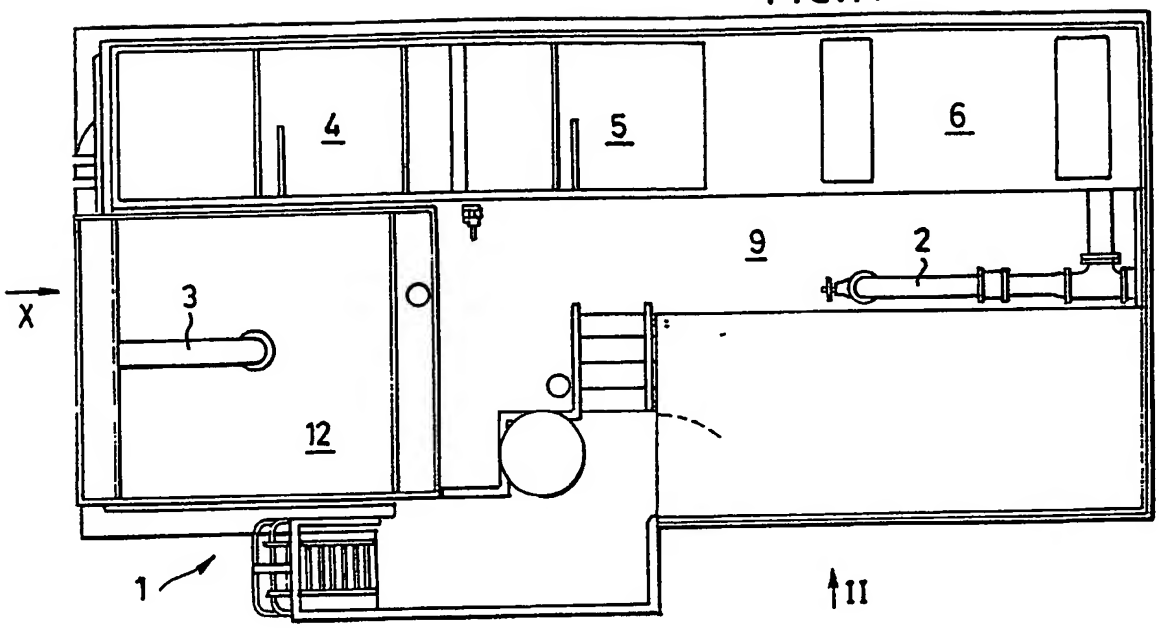


FIG.2.

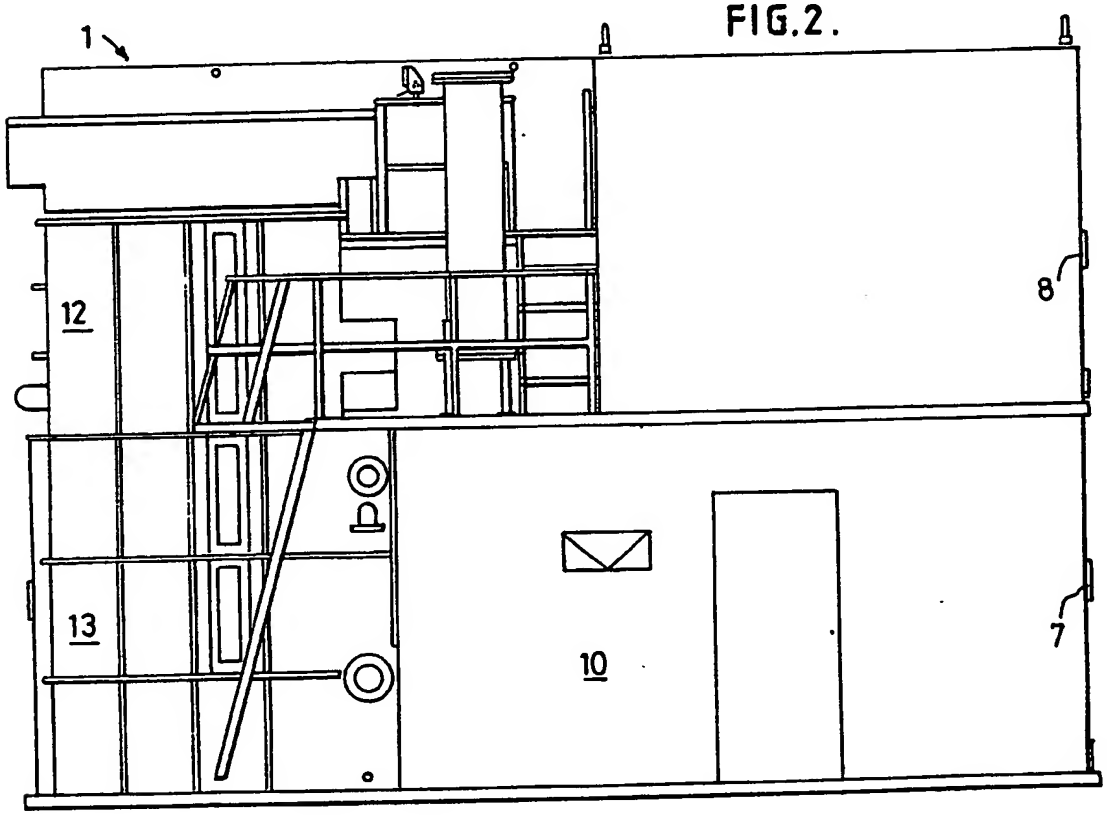


FIG.3.

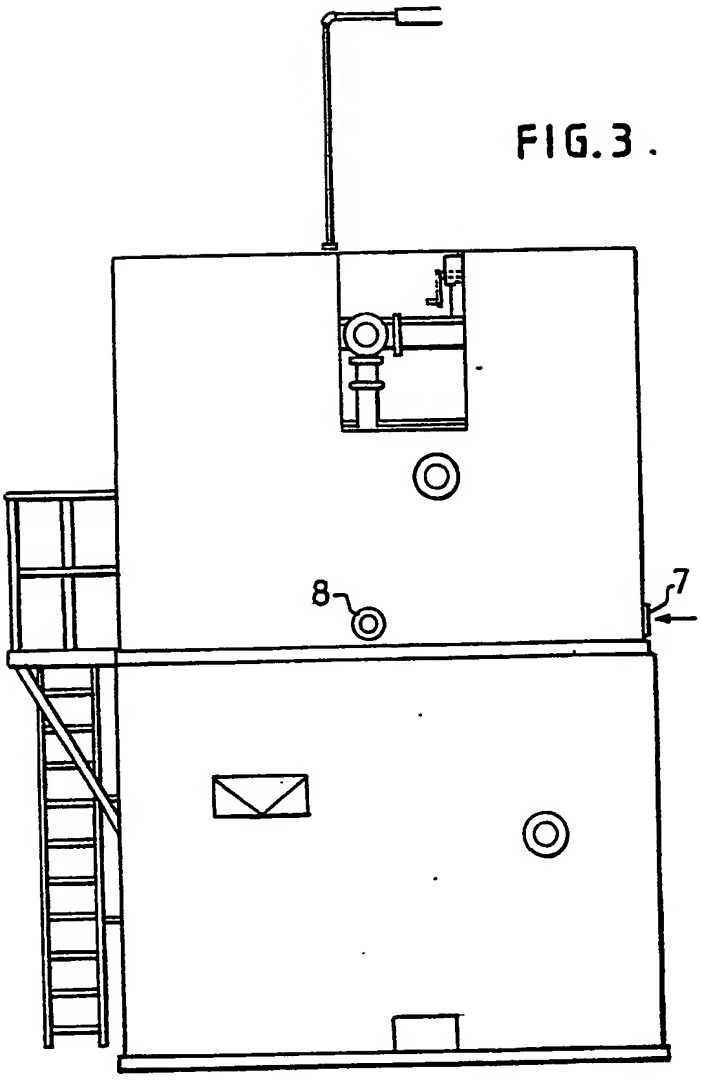
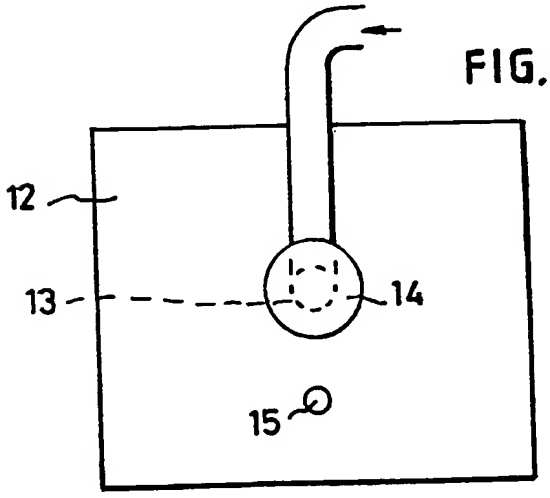


FIG.4.



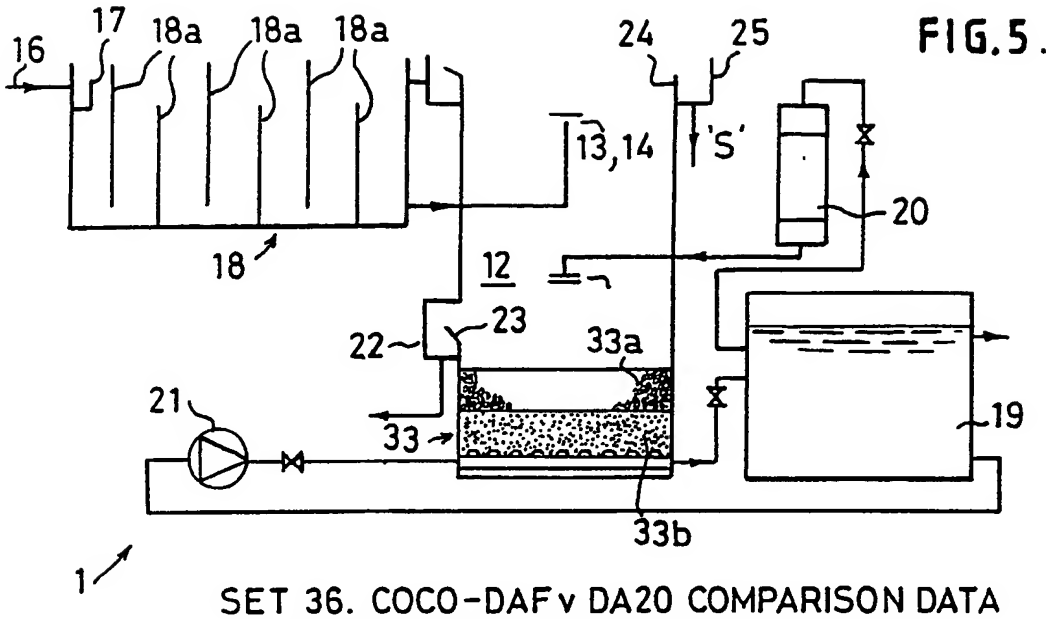

16
17
18a
18a
18a
24
25
13,14
'S'
20
18
12
22
23
33a
21
33
19
33b
1

FIG.5.

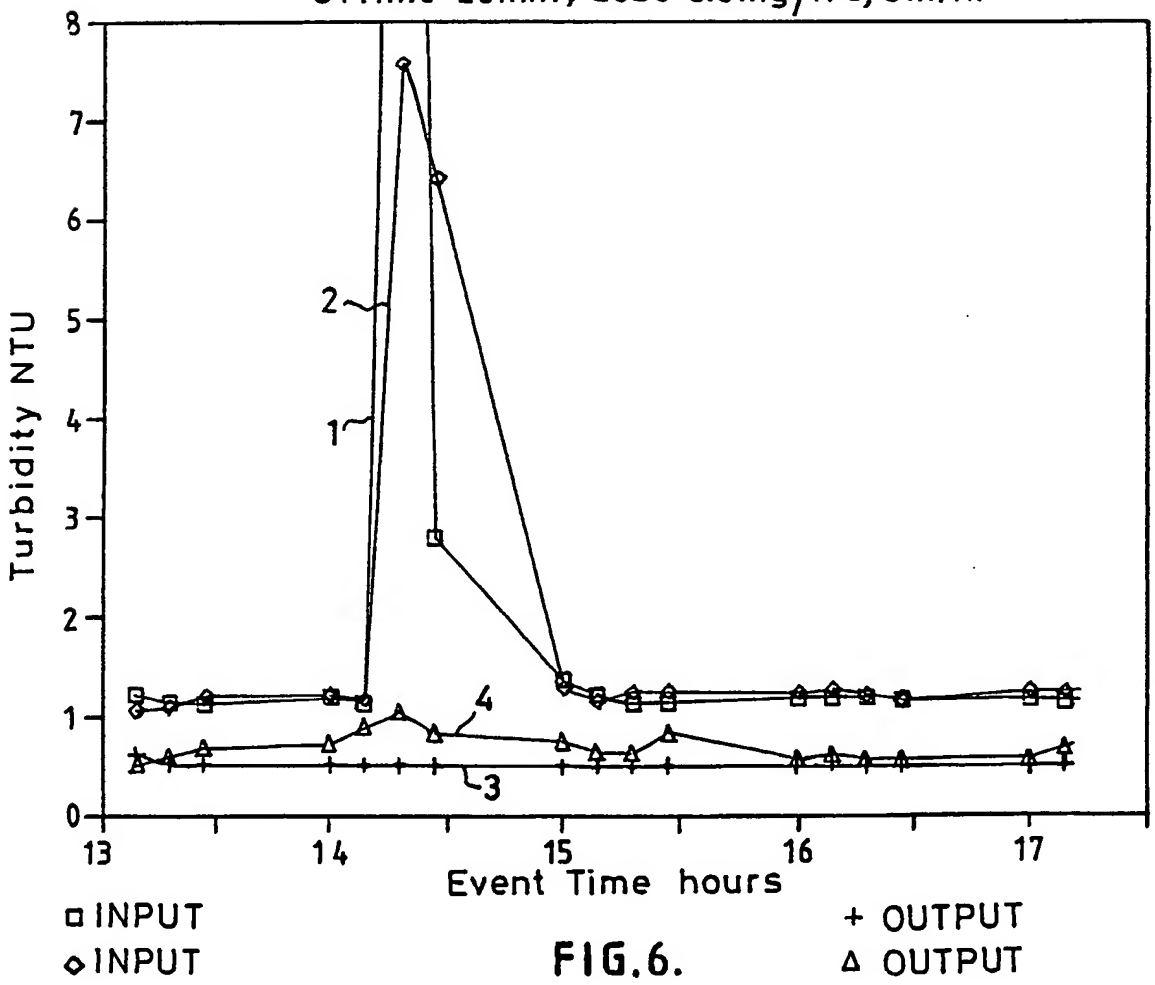

SET 36. COCO-DAF v DA20 COMPARISON DATA
C. Time 20min, dose 3.0mg/lFe, 8m/hr
Turbidity NTU
0
1
2
3
4
5
6
7
8
13
14
15
16
17
Event Time hours
1
2
3
4
□ INPUT
◇ INPUT
+ OUTPUT
Δ OUTPUT

FIG.6.

DISSOLVED AIR FLOTATION

The invention relates to dissolved air flotation, particularly such flotation as used as a primary treatment process in water treatment plants.

In such a process, water saturated with dissolved air is generally released into a stream of pre-flocculated raw water. On release, the air comes out of solution, nucleating into a stream of bubbles of a few microns in diameter. The bubbles attach to the floc, enhance its buoyancy, and cause it to float to the surface, whence it may be removed. The dissolved air is usually released into the raw water stream such that the main throughput carries the air into a residence tank. The floc then floats to the surface and is removed by a suitable system such as hydraulically or mechanically, using a scraper system. This system is however expensive in terms of capital expenditure and operating expenditure, as well as on space (land), in that a relatively large installation is required which in turn requires high power and mechanical costs.

It is accordingly an object of the invention to seek to mitigate these disadvantages.

Using the invention, the released impurities can then be removed by some suitable means.

According to a first aspect of the invention there is provided a method of removing particulate impurities from a liquid, characterised by providing a vessel, by providing a liquid containing particulate impurities, by providing a source of bubbles of gas, by forming a zone of bubbles in the liquid, and by passing substantially all incoming liquid through the bubble zone, whereby bubbles adhere to the particulate impurities in the liquid and cause flotation

thereof.

The method may include the step of releasing the bubbles at a distance below an inlet to the vessel for the liquid. This ensures that all incoming liquid passes through the zone of bubbles, particularly where as is preferred the liquid and bubbles pass in counter-current flow relation. This ensures an optimum particle/particle contact and bubble/particle contact.

The source of bubbles may comprise the liquid supersaturated with the gas. This is an efficient use of the liquid, which can be recycled to provide the gas and to act as a carrier therefor.

The method may include the step of providing that the rising or floating particles flocculate during rising to the liquid surface. This provides for efficient separation of the impurities and carriage thereof to the surface, particularly where the particulate impurities may combine with each other and/or with sinking particulate material.

Preferably the zone of bubbles may extend substantially over the cross-sectional area of the vessel. This provides for full contact of the impurities with the bubbles, and efficient impurities' removal.

The zone of bubbles may be continuously maintained. Thus there is always a layer or blanket of bubbles operative to strip impurities from the liquid.

There may be the step of providing a filter means through which the liquid passes after contact with the gas bubbles. This provides for efficient cleaning of the liquid.

The step of regeneration of the filter means may be included in the method, particularly a backwashing step.

The method may include the step of de-scumming the liquid. This step may be carried out by raising the level of the liquid in the vessel. This is a relatively simple operation.

According to a second aspect of the invention there is provided apparatus for removing particulate impurities from a liquid, characterised by a vessel, a source of liquid containing particulate impurities, and a source of bubbles of gas adapted to provide in use a zone of bubbles in the vessel through which zone incoming liquid passes.

The source of bubbles of gas in the vessel may be below an inlet for the liquid to the vessel. This provides for full contact of the liquid and bubbles.

The source of bubbles of gas may comprise a nozzle means through which is dispensed liquid supersaturated with gas. This provides for a uniform dispersion of the gas.

The gas may be air. This is a relatively inexpensive source.

There may be means to maintain the zone of air continuously in the vessel. This provides for an efficient operation of the apparatus.

There may be a filter means downstream of the zone where the bubbles and impurities combine. This provides a compact structure, particularly where the filter means is in the vessel.

For efficient filtering, the filter means may comprise a bed of anthracite on sand,

or alternatively sand.

There may be means to backwash the filter means. This provides for an efficient operation of the apparatus.

The nozzle means may comprise a ramified means having spaced apart nozzles, or alternatively a single nozzle means. Either embodiment provides a bubble zone across substantially the whole cross-sectional area of the vessel nozzle. The nozzle means may be adjustable in position. This provides for adjustability according to desired operating parameters.

There may be a curved side weir plate means at a side of the vessel opposite that from which sludge is removed. This provides for a horizontal hydraulic force on the scum to be removed, so facilitating removal thereof.

There may be a flocculator means upstream of the vessel. This enhances impurities' separation, particularly where the flocculator means may comprise a plurality of flocculation tanks through which the liquid flows in series.

The flocculator means, and vessel may be in a single unit. This provides for a compact structure which does not take up a great deal of space.

It will be understood that the apparatus may be incorporated in an existing flocculating filtering vessel.

In either case, the air from the nozzle means provides a blanket of fine air bubbles, suitably micro-bubbles through which incoming liquid to be treated must flow to provide a flotation stage in the zone before the treated liquid, from which the main impurities have been removed by flotation, passes before

continuing on in the same direction, counter to the air flow, to the filter.

It will be understood that liquid to be treated includes sewage, raw river water in storage in say a reservoir, water containing algal blooms, and to "clean" and "dirty" water treatment processes.

The apparatus may be used in retrofits to not only rapid gravity and roughing filters, but also to what are known as Flat Bottom Clarifiers (FBC) or Sedimentation Tanks. In the latter the invention's air blanket would replace what was the function of a sludge blanket, performing the filter quicker and more efficiently. Moreover, the filter means may comprise a biological aerated filter (BAF).

A method and apparatus embodying the invention are hereinafter described, by way of example, with reference to the accompanying drawings.

Fig.1 is a plan view of apparatus for carrying out a method according to the invention;

Fig.2 is a side elevation view thereof taken in the direction of arrow II in Fig.1;

Fig.3 is an end elevational view thereof;

Fig.4 is a schematic plan view of a modification of the part 'X' of the apparatus of Fig.1;

Fig.5 is a schematic flow diagram showing flow through the apparatus of Fig.4; and

Fig.6 is a graphical representation of the efficacy of method and apparatus according to the invention.

Referring to the drawings in which like parts are shown by like reference numerals, there is shown apparatus 1, for removing impurities from liquid stream such as water containing particulate impurities from a raw water feed comprising a source 2 of water, a source of gas 3, suitably dissolved air under pressure, and means to pass the gas into the water, in counter-flow relation thereto whereby to adhere bubbles of gas to the impurities and cause same to rise to the surface.

The apparatus 1 as shown comprises a unitary structure in which compartments 4, 5 and 6 of a single tank are separated by internal baffles so as to provide a serpentine path to enable a residence time sufficient to induce flocculation. 6 is hooded for ozone off-gas capture. The compartments have alternative inlets 7, 8 and outlets. The top of the compartments 4, 5, 6 is adjacent an elevated walkway 9 situated over a sludge collection tank which is in turn situated over a control room 10 in which a source comprising air is situated.

There is a flotation tank 12 situated above a filter bed 13, in the embodiment, of anthracite on sand, though it will be understood that any suitable material may be used for the filter, such as sand per se. In Fig.1, the inlet for water supersaturated with air is in the form of an inlet manifold leading to a ramified structure comprising a grid of, in the embodiment, upwardly directed nozzles arranged in a generally orthogonal array so as substantially to extend over the surface area of the tank. There are six nozzles, arranged in two banks of three, though there could be more or less as desired. The nozzles may be releasably secured as by screwing to the manifold so that they can be separated therefrom for ease of transport. Also, the dimensions of the grid can be adjusted by adding

or removing one or more nozzles, or by 'clipping-off' an existing nozzle.

The raw water fed into the apparatus 1 is pre-treated by flocculation in the tank 4, 5, 6 before being fed to the flotation tank, where it passes in counter-current flow to the air bubbles. The nozzles are below an inlet to the tank or vessel 12 for pre-treated liquid, so that a zone of air micro-bubbles extends across substantially the whole of the surface area of the tank 12. The air bubbles are initially dissolved in the water, but come out of solution when they emerge from the nozzles to form the micro bubbles which effectively form a blanket of air across the whole tank, the air bubbles adhering to the impurities in the pre-treated water and raising them to the surface where it is discharged from the tank over a weir intermittently and in a controlled manner. The apparatus 1 is under automatic control using ultrasonics and based on data relating to on-line flow and turbidity, with protection against process failure and deterioration in water quality.

In the modification of Fig.4, the tank 12 contains an upwardly directed inlet nozzle 13 with a trumpet or bell-end and a spaced covering 14, suitably conical, for directing the treated liquid into the tank. The riser diameter is such that the exit velocity of the flocculated water is small, an in-pipe velocity of $< 0{,}3 m\ sec^{-1}$ being preferred. This helps to avoid damage to the sludge blanket and disruption to the flotation zone by large, high energy, toroidal vortices. An inlet spacing of $1/4m^2$ for the single inlet requires careful monitoring of the fluid flow velocities at the inlet and outlet of the inlet pipework. High inlet velocities require a large inlet cone (as herein referred to) to dissipate flow energy, which would otherwise lead to high exit velocities or shedded vortices which can damage the sludge blanket. A short inlet cone provides good flotation results, with a low inlet velocity ($< 0.35m\ sec^{-1}$) leading to low exit velocities $< 0.04m\ sec^{-1}$.

A single air diffusing nozzle 15, situated below the level of the lowest part of the inlet riser, is situated adjacent the riser. This simplified structure saves on pipework, and also distributes incoming liquid in such a way as to achieve quiescent flow conditions, so enhancing the formation of a stable air bubble zone.

Referring to the schematic view of the apparatus 1 shown in Fig.5, influent or water to be treated 16 is flash mixed in a dosing weir 17 with a flocculating agent, such as ferric sulphate solution from a sparge pipe, and then passes from the weir 16 to a seven chamber hydraulic flocculator 18 (similar to the chambers 4, 5, 6) where floc is formed as the water follows a sinuous path under and over baffles 18a. The height of the weir 17 is adjustable. Also the weir may include projecting fingers, to break up the flow plane of the water to allow the flocculating agent to enter the water before a turbulent zone, so aiding mixing.

The flocculated water then passes via the nozzle 13 and cover 14 into the tank 12, as shown. The exit velocity of the water from the nozzle 13 is about 0.04m sec $^{-1}$ (at 10m per hr, flotation rate) with the inlet cone having a diameter of 600mm exit diameter providing a gradual reduction of the exit velocity to 0.04m sec $^{-1}$. The nozzle 13 is positioned about 700mm below the top water surface.

Micro-bubbles of air come out of solution as the water emanates from the nozzle 15 and form a zone or blanket of micro-bubbles right across the whole surface area of the tank 12. The bubbles form a zone about 1 metre deep below the nozzle 13. The air rises and the water flows downwardly as viewed (as in Figs. 1 to 3), through a filter 33, comprising a layer of anthracite 23a on a layer of sand 23b. The filter in the embodiment is suitably 1m high, the anthracite layer being 400mm thick and the sand layer 600mm thick.

The clean water then passes out of the tank 12 and filter 33 to a clean water holding tank 19. Some of the water from tank 19 is recycled to provide the source of micro-bubbles. The water is passed to a saturator 20, packed with suitable plastic contact media such as Pall rings, where it is contacted with air under pressure from a compressor, the air flow being controlled by a float system.

The air is dissolved, the water becomes supersaturated with air and then the water supersaturated with air is passed back to the tank 12. The recycle water flow rate combined with the saturator pressure determine the amount of air being supplied to the vessel 12. A suitable recycle flow rate is a volumetric throughput of 10% of the process flow. Thus the liquid itself is used to provide a carrier for the air-forming micro-bubbles. Some of the water from tank 19 is also used to provide a backwash facility for the filter bed 33.

Water is pumped by a pump 21 through the filter from the bottom as viewed. The backwash water passes out through a washout weir 22 which has a lip 23 over which the water flows, any displaced filter medium falling back from the lip 23 to the filter bed 13.

Scum is collected on the surface of the liquid in the tank 12 and it is removed periodically by raising the level of the water in the tank 12 by operation of suitable valving, some valves of which are shown at FCV in Fig.5, to raise the liquid level and decant scum over a weir 24 into a channel 25 from which it can be removed, see arrow 'S'. There is a weir with a curved lip, known as a ski-jump weir, which provides a horizontal flow of liquid at its surface across the tank 12. This is achieved in that influent 16 is passed to the ski-jump weir, again by suitable valve operation, to pass influent over the weir so as to push the scum laterally to the channel 25.

The counter-current flotation aspect allows the filter bed 33 to run for extended periods, even during high algal bloom loads, without the need to backwash at greatly increased frequencies. The apparatus 1 can thus operate in a peak-lopping mode and flotation in tank 12 could be discontinued when raw water inlet quality is good, so saving on the cost of continuous operation. The de-scumming operation referred to may be carried out without stopping the flotation and filtration process.

In a practical embodiment, referring to Fig.6, the plots on the graph show results of running apparatus according to Figs. 1 - 3 against a flotation apparatus which does not have counter-current flow. The two apparatus were operated with identical process parameters and on the same process water. It can be seen that apparatus according to the invention (plot 2) (inlet) is much better than the non-inventive one (plot 1) (inlet) and respective outlet (plot 3, invention, plot 4, non invention).

The outlet turbidity, plot 3, is flat i.e. remains completely unchanged, unlike the peaked outlet of plot 4 which has risen to mirror the inlet and takes time to recover to the original output quality. Thus hysteresis has been eliminated in the invention, and this leads to more effective removal, and control.

It will be understood that the term "flocculate" used herein is to be taken to mean a "pre-treatment".

It will be understood that the counter-current flotation/filtration method and apparatus described herein has advantages. Thus by releasing the dissolved air at some depth below the inlet of raw water, a blanket or zone of fine micro-bubbles can be generated through which the entire raw water flow must pass. Thus there is potential for greater particle/particle contact and also particle

bubble contact. This provides enhanced flocculation and flotation and removes the need for a one to one ratio of flocculator to floater. Also by releasing air below the flocculated water, a high energy air release zone is separated from a high floc concentration zone, thus removing the potential for floc damage in the process stream. The limitation on size of units, due to lack of air in the sludge, is also negated as the air supply is uniform throughout the cross sectional area of the process vessel, and is continuously supplied. Moreover, by having flo/filtration the flotation system is on only when necessary and this saves on the high operational costs of flotation by turning it off when the raw water quality is good. The method and apparatus reduce the amount of capital investment in plant as that plant is not operating in good raw water quality conditions, and reduces the amount of flocculators required for treatment and removes the need for separate flotation vessels altogether.

In a comparison , over three days under high algal load conditions, with standard dual media filters and the method and apparatus of the invention, the invention used 1.5% of the throughput volume for backwashing and the dual filter media 15%, a major saving in volume of wash water required.

CLAIMS

1. A method of removing particulate impurities from a liquid, comprising the steps of providing a vessel, providing a liquid containing particulate impurities, providing a source of bubbles of gas, by forming a zone of bubbles in the liquid, and by passing substantially all incoming liquid through the bubble zone, whereby bubbles adhere to the particulate impurities in the liquid and cause flotation thereof.

2. A method according to Claim 1, comprising the step of releasing the bubbles at a distance below an inlet to the vessel for the liquid.

3. A method according to Claim 1 or Claim 2, comprising the step of passing the liquid and bubbles in counter-current flow.

4. A method according to any preceding claim, the source of bubbles comprising the liquid supersaturated with the gas.

5. A method according to any preceding claim, comprising the step of providing that the rising or floating particles flocculate during rising to the liquid surface.

6. A method according to Claim 2, the particulate impurities combining with each other and/or with sinking particulate material.

7. A method according to any preceding claim, the zone extending substantially over the cross-sectional area of the vessel.

8. A method according to Claim 7, the zone of bubbles being continuously maintained.

9. A method according to any preceding claim, comprising the step of providing a filter means through which the liquid passes after contact with the gas bubbles.

10. A method according to Claim 9, comprising the step of regeneration of the filter means.

11. A method according to Claim 10, the regeneration step comprising a backwashing step.

12. A method according to any preceding claim, comprising the step of de-scumming the liquid.

13. A method according to Claim 12, comprising the step of raising the level of the liquid in the vessel to effect de-scumming.

14. A method of removing particulate materials from a liquid, substantially as hereinbefore described with reference to the accompanying drawings.

15. Apparatus for removing particulate impurities from a liquid, comprising a vessel, a source of liquid containing particulate impurities, and a source of bubbles of gas adapted to provide in use a zone of bubbles in the vessel through which zone incoming liquid passes.

16. Apparatus according to Claim 15, the source of bubbles of gas in the vessel being below an inlet for the liquid to the vessel.

17. Apparatus according to Claim 16, the source of bubbles of gas comprising a nozzle means through which is dispensed liquid supersaturated with gas.

18. Apparatus according to Claim 17, the gas being air.

19. Apparatus according to Claim 18, comprising means to maintain the zone of air continuously in the vessel.

20. Apparatus according to any of Claims 15 - 19, comprising a filter means downstream of the zone where the bubbles and impurities combine.

21. Apparatus according to Claim 20, the filter means being in the vessel.

22. Apparatus according to Claim 21, the filter means comprising a bed of anthracite on sand.

23. Apparatus according to Claim 21, comprising the filter means comprising sand.

24. Apparatus according to any of Claims 20 - 23, comprising means to backwash the filter means.

25. Apparatus according to any of Claims 17 - 20, the nozzle means comprising a ramified means having spaced apart nozzles.

26. Apparatus according to any of Claims 17 - 24, the nozzle means comprising a single nozzle means.

27. Apparatus according to Claim 25 or 26, comprising the nozzle means being adjustable in position.

28. Apparatus according to any of Claims 15 - 27, comprising a curved side weir plate means at a side of the vessel opposite that from which sludge is removed.

29. Apparatus according to any preceding claim, comprising a flocculator means upstream of the vessel.

30. Apparatus according to Claim 29, the flocculator means comprising a plurality of flocculation tanks through which the liquid flows in series.

31. Apparatus according to any of Claims 15 - 30, the flocculator means, and vessel being combined in a single unit.

32. Apparatus for removing particulate impurities from a liquid, substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9301721.8

Relevant Technical fields

(i) UK Cl (Edition L) C1C (CRDD,CSDD,CTDD,CJB,CJC, CKB,CKC,CKD,CLB,CLC,CLD)

(ii) Int Cl (Edition 5) C02F 1/24

Search Examiner

G M BRIDGES

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Date of Search

28 APRIL 1993

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2090240	A (PIELKENROOD-UMITEX NV) see description with regard to Figure 2	1,2,4-6, 8,12, 15-19
X	GB 1544494	(STAMICARBON) - see eg Claim 1 and page 2 lines 11 to 14	1-3,5-8, 12,15-16
X	GB 1531775	(SWIFT & CO) - see whole document	1-3,5-7, 12,15-16
X	GB 1496191	(CLARKE CHAPMAN) - see eg description with regard to Figure 1 (and especially page 2 lines 80-86)	1,2,5,6, 8-12,15, 16,20-24, 29,31
X	GB 1473481	(SWIFT) - see whole document	1,5,6,8, 15,29
X	GB 1194850	(SAINT-GLOBAIN) - see eg page 2 lines 117-121	1-3,5-8, 12,15,16
X	GB 1036679	(PARAC) - see eg description with regard to the figures	1,2,4-6, 8,12, 15-19,29, 31
X	GB 837373	(SUNIYA) - see description with regard to Figure 1	1-3,5-8, 12,15,16

Category	Identity of document and relevant passages	Relevant to claim.

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

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Application number

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Relevant Technical fields

(i) UK Cl (Edition) Contd. from page 1

(ii) Int Cl (Edition)

Search Examiner

G M BRIDGES

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

28 APRIL 1993

Documents considered relevant following a search in respect of claims

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	US 4274959	(TECHTRANSFER GMBH) - see abstract and figures	1-7,12, 15-19
X	US 4176058	(GROBLER) - see Figure 1	1,5-8,12
X	US 3836460	(WILLIS) - see whole document	1,2,5-12, 15,20,24

Category	Identity of document and relevant passages	Relevant to claim(s)

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